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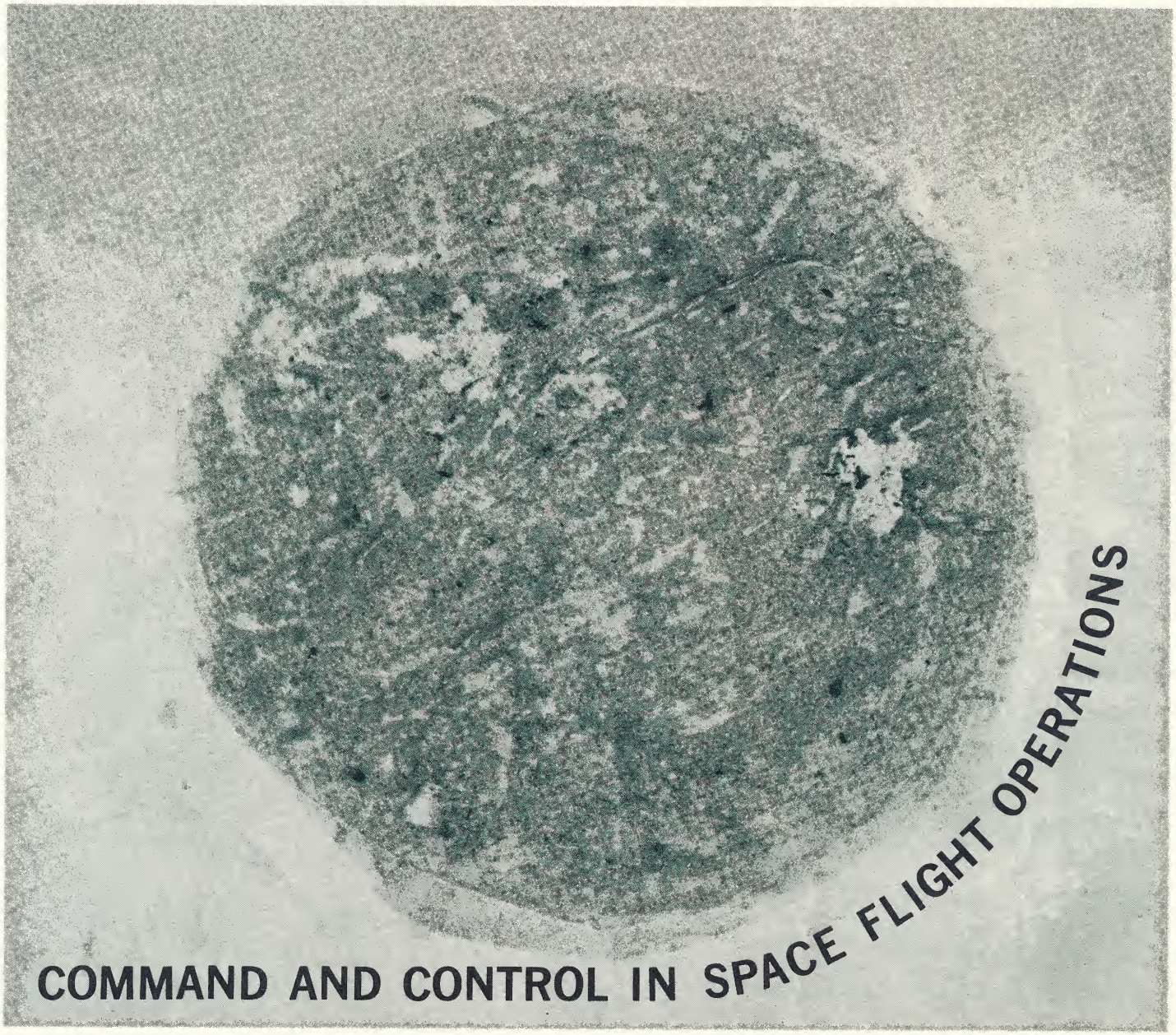
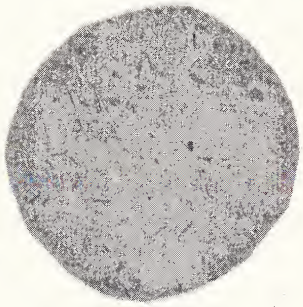
CSC REPORT



COMMAND AND CONTROL IN SPACE FLIGHT OPERATIONS



A CSC team of real-time analysts discusses JPL'S SFOF system (left to right: Carroll Reed, Roland Taub, Pat Callahan, Paul Kazek, and Howard McCoy).

COMMAND AND CONTROL IN SPACE FLIGHT OPERATIONS

By PATRICK H. CALLAHAN, CSC Scientific Applications

CSC's Scientific and Military Applications Department has developed a computer program system for the California Institute of Technology's Jet Propulsion Laboratory to provide the base for JPL's new Space Flight Operations Facility (SFOF) which will be used to control NASA unmanned lunar and interplanetary space probes. Modifications and improvements to the SFOF system to be accomplished by CSC in the coming year will support Mariner and Surveyer spacecraft launchings in 1964 and 1965.

To achieve time-shared, real-time handling of space flight operations, the JPL facility utilizes a configuration of IBM computers, including a Central Processor (7094), I/O Processor (7040), Disk Files (1301), and Real-Time Data Channel (7288). Switching capability for these devices allows them to be connected in eight different configurations. The complexity of the interface between the equipment modules can be seen by the diagram on following page which illustrates the equipment configuration. The 7040 serves primarily as an I/O controller for the 7094. It also provides some general capabilities, such as real-time data prints and plots. The 7094 performs mathematical calculations for such functions as orbit determination, telemetry reduction, trajectory analysis, and space science experiment analysis.

The I/O Processor

The principal means of communication between the user and the computer system is the message composer. This device provides a 72-character line of typewriter input. A line is typed and displayed, and transmission to the computer is accomplished by pressing a button when the line is complete. A typical message would be as follows:

DISPLAY, D1, RT, F21 $

"DISPLAY" is the command word, indicating the type of action desired by the user such as in this example: 7040 output processing. "D1" is "device number one," the bulk printer. "RT" indicates that real-time telemetry is the desired data type. "F21" refers to format 21, which was stored on disk at initialization. (The format contains up to 14 data names and other associated fixed parameters which are necessary for the program to produce printed displays.) Similar messages are available for tracking as well as telemetry data, and plots as well as prints. Other messages are used to control and communicate with 7094 programs. Recovery from hardware failure by switching in this full-duplexed configuration is also controlled through the message composer.

All communications from the system to the user appear on an administrative printer at each station where all message composer inputs are recorded with an error indication when an input is erroneous. System messages to the users, such as detection of machine errors, spacecraft telemetry alarm conditions, and system overload conditions, are also recorded here.

A card reader is included in the user area for several purposes. It is used for the input of control cards, for the input of data decks to the 7094 programs for mathematical calculations, and input of engineering unit conversion coefficients as well as alarm limits for 7040 telemetry processing. It also serves as backup in case of message composer failure. The message com-

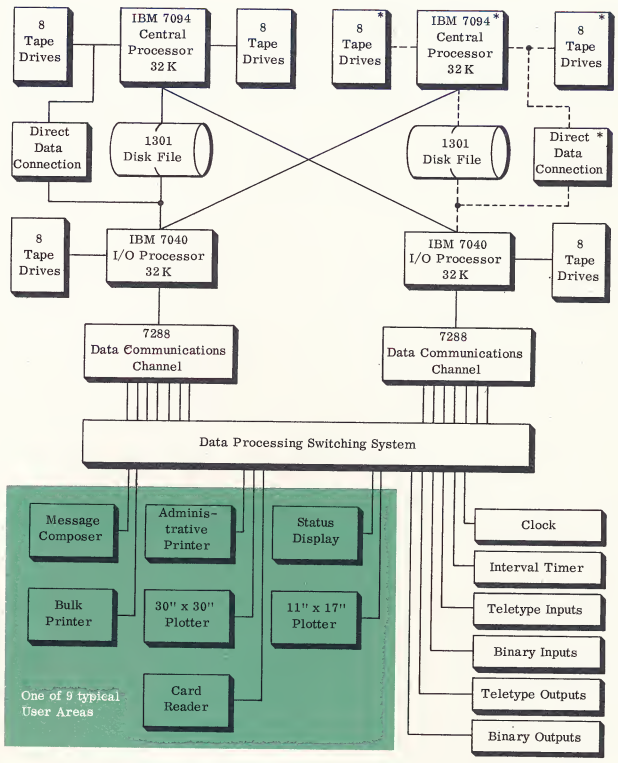
poser, in turn, backs up the card reader.

Two different plotters (30″ x 30″ and 11″ x 17″ strip chart) and a bulk printer constitute the primary display capability of the system. In addition to the system's real-time telemetry print capability, there are several other types of displays. The 7040 also possesses the capability of generating real-time tracking and telemetry plots and prints. Requests for display data which have already been stored on the disk file are satisfied by the 7094 system. The output provided by the system is restricted because of core memory size to tabular printouts and plots of a variable against time. A 7094 program being operated from a user station, however, has complete flexibility in use of the output devices. Output is placed on the disk file in the proper format, and the system makes it available at the user stations, either on a when-generated basis or as the result of a specific request.

The 7040 has several functions which it performs without user requests. All input data is identified, sorted, decommutated if necessary, and placed on the disk in the correct file. Spacecraft alarm monitoring of telemetry data is performed, checking against the high and low limits prescribed by the users for each measurement. In addition, a historical tape record is made of all raw data inputs (which may also be used in post-flight analysis or as an input tape for simulation).

The keystone of the 7040 program system is the priority control mechanism. Programs may be divided into two classes: trap processors and ordinary processors. The priority of the trap processing programs is assured by the equipment: trap processors interrupt other processors continuously. Therefore, the highest priority operations are conducted by the programs controlling the inputs and outputs to and from the disk file, the data communications channel, and the tape drives, in order that no inputs or outputs are lost. When these programs have completed operation, and no unexecuted I/O commands are queued up, they transfer control to the ordinary processors. Disk and tape trap processors return to the point of interrupt. The 7288 trap processor gives control to PRIO (Priority Control Program) for all input traps.

The ordinary processors in the priority list are ordered in accordance with the importance of their services to the mission. Input processors are highest in priority, so that no inputs are lost. Output processors are lower and diagnostics lowest of all. After an input trap occurs, PRIO checks from the top of the list to see if the ordinary processor for that type of data should be operated. The ordinary processor which was "turned on" by the trap processor is initiated from its beginning. When it has completed operation (this may be after several other trap processors have been entered and operated), it returns to PRIO for another cycle of the priority list, again from the top. Eventually, working down the list of "turned on" programs, the PRIO program will find a program "turned on" that had been entered before and then interrupted by a trap. In this case, machine registers are restored and the program is resumed at the point of the previous trap interrupt. In this way, programs high in priority will *always* operate whenever there is a processing requirement. The trap processor turns them on and PRIO soon operates them. Alternatively, some programs, low in priority, may not be able to keep up with their task if the system load is heavy. However, this type of system works as well as any other up to the point of overload. At this juncture, the most critical functions are still performed successfully with as much total system effectiveness as is possible under the circumstances.



* Final configuration includes a 7094 and disk file not present in the initial configuration.

SFOF Real-Time Computer and Input/Output Configuration

The Central Processor

The Central Processor's SFOF Monitor System is responsible for coordinating the input-output functions and also the time-shared operation of the resident user programs. These programs perform the bulk processing and complicated mathematical calculations necessary in space flight operations.

The monitor provides these programs with the necessary communications with the user areas. These communications are accomplished by means of the direct data connection to the 7040 and the disk file. Subroutines are provided to coordinate and facilitate input or output from any user area device, the disk file, and tape storage. User programs reside on the disk file; the input and output other than tape is also obtained through the disk.

User programs for the 7094 also operate in accordance with a priority list (which may be changed in real-time). The list contains information for each program as to whether it is to operate and for what percentage of the time. The time period called "run time," covered by the priority list is divided into slices called "min time." Each program which is turned on in the priority list operates for "min time." At this point, it is interrupted and saved on the disk file, to be read in and continued when its turn reoccurs in the cycle. The succeeding programs operate for their minimum times, each in turn, until a program has operated for its allocated percentage of run time. When "run time" has elapsed, the whole cycle repeats again.

In this manner, the requirements of all users can be best satisfied for the period of available computer time. Users are alerted when their programs are operating by a status display of the program name in the user area. By providing a sufficient "min time" for programs to accomplish some useful output under normal conditions, users in each area will be served promptly and properly by the available data processing capabilities. ■

COMMERCIAL APPLICATIONS WINS STOCK TRANSFER CONTRACT

CSC's Commercial Applications Department was awarded a contract this month to design and implement programs on the IBM 7080 for stock transfer procedures at the corporate offices of Lockheed Aircraft Co., Burbank, California. This will mark the first year that Lockheed Aircraft will perform this function on its computer.

SERVICE BUREAU TO OFFER ON-LINE COMMUNICATIONS

Customers at CSC's Service Bureau will soon be provided with an on-line data communications system. Computer time on CSC's 1107 will be made available to users throughout the country by installation of a UNIVAC Data Line Terminal. This application of direct on-line data transmission is the first to be offered by any service bureau and will be especially suited to users with UNIVAC 1004 card processors and standard Dataphone sets.

Transmission up to 342 characters per second will provide users with problem solutions on the 1107 within minutes after input of their data from various remote locations.

HOUSTON DIVISION RECEIVES DEL WEBB CONTRACTS

Three contracts in pricing and inventory control programming were received recently by CSC's Houston Division from the Del Webb Corporation. Programs will be prepared by CSC on the IBM 1401 to assist in the development of statistical controls for various construction projects planned by Del Webb in the Houston area and for the southwestern United States.

NEW INPUT TO CSC ADDS 20 MAN YEARS

Three new members joined CSC's technical staff last month, bringing more than 20 man years of additional computer experience to the company.

Appointed to the Scientific Applications Department was Robert R. Hall, formerly of Northrop. Mr. Hall has specialized in programming and numerical analysis for such applications as gas dynamics, wind tunnel routines, and missile trajectory analysis.

New additions to CSC's Palo Alto facility include John B. Patchen, formerly in systems design and analysis for RCA, and Colburn H. Marceau, an analyst in business programming for General Electric.

CSC STAFF APPEAR IN NATIONAL TRADE MAGAZINES

An increasing output by CSC staff members has resulted in acceptance by national trade and professional publications of a variety of technical papers.

Articles by Donald Stewart, Roger Fulton, Allan Harbaugh, and George Sutton have appeared in the *IEEE Transactions* (June), *Datamation* (August), *Business Automation* (October), and *Data Processing for Science/Engineering* (November).

CSC

PROFILE

From a brief tour in the Royal Canadian Air Force as a commissioned Flying Officer (grounded by virtue of sex) to taste tester on non-military foods, EMILY McCORMICK stands 5'3" and several giant steps apart from the stereotype often affixed to programmers of the distaff side.

"Pooky," a handle awarded Emily by her Canadian parents and one which she prefers, expresses a special fondness for maple trees or trees of any bent which might enhance the decor of the more arid regions in southern California. A native of Sudbury, a heavily wooded area in Ontario, Pooky is critical of tree cutters, freeway planners, and less fortunate folk unaware of the esthetics associated with a preponderance of foliage.

The groundwork for Pooky's vocational direction was provided at the University of Toronto where she received her degree in mathematics. She entered the equivalent of our AFROTC program as a flight cadet and graduated with a lieutenant's commission and the option to resign after summer camp. She exercised the latter with considerable dispatch following the realities of initial RCAF training.

Pooky's first civilian position was with the General Foods Research Center in Tarreytown, N.Y. As a junior technologist, she ran the gambit from taste testing Jello and coffee preparations to statistical analysis of the tastes she had tested. Pooky was promoted to the management of an analysis section but left after several unsavory experiences with soy bean flour.

A substantial distance from the home of the big soy bean, Pooky decided to continue her education at the University of Southern California, where she obtained her Master's degree while earning tuition and sports car payments lecturing freshman classes in algebra and calculus. As a faculty member in the mathematics department at USC for three years, she found herself treating both academic and sociological problems of her students.

Applying her talents in mathematics and science at CSC since March, 1962, Pooky has contributed to orbit determination studies and such work as the separation of bodies in outer space and a system of 12 second-order differential equations. She is presently employed on programs for piping flexibility analysis.

Pooky enjoys sporting about in her Sprite, and is presently eyeing the Jaguar XKE. CSC sages are debating whether Pooky wants to race at Riverside or beat the weekend traffic to Big Bear. She might do both!

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